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## **Space Tools for Servicing, Repairing, and Maintaining Spacecraft**

Just like mechanics and technicians on Earth, astronauts use a variety of manual and portable power tools in space to repair, service, and maintain spacecraft, like the Space Shuttle and the International Space Station (ISS), and other satellites, like the Hubble Space Telescope (HST). Space tools are divided into two main operating categories: Intravehicular Activity (IVA) tools and Extravehicular Activity (EVA) tools. IVA tools are used by astronauts inside the pressurized habitable compartments of a spacecraft for routine maintenance, repair, and unexpected tasks. EVA tools are used by space-suited astronauts outside of their pressurized spacecraft in the vacuum of space.

### **IVA Tools**

Most IVA tools are unmodified, commercially off the shelf, high quality hand and power tools. These IVA tools are used for many general tasks known as in-flight maintenance (IFM), such as removing fasteners on access panels to electronics racks and to repair or adjust mechanical and electrical equipment or experiments. These IVA tools are similar to those used by mechanics and electronics technicians. Examples of IVA tools are various sizes of wrenches and sockets, hexagonal, Phillips, and torque head drivers, pliers, and ratchets. Other general-purpose IVA tools are the hammer, pry bar, vise grips, files, and hacksaw. Special purpose IVA tool kits to repair electrical cables and connectors are also carried on board the Space Shuttle and the ISS.

### **EVA Tools**

Due to the extreme space thermal and vacuum environment, most EVA tools are specially designed hand and portable power tools that can be easily operated by an astronaut in a pressurized space suit. EVA tools must be designed with unique requirements for their successful use in repairing and servicing spacecraft. Fine motor activity is difficult when operating tools with a space suit gloved hand. Most space tools are designed to be operated with one hand since the other hand may be required to react the forces generated when operating the tool. EVA tools also have to be designed with handles that fit the natural shape of a pressurized space suit glove. The most unique and important EVA tool requirement is the need to provide a feature for tethering the tool at all times to prevent it from floating away if it is inadvertently released. This feature is usually a small ring that is built or added to the tool. The astronaut has an equipment tether with an easily operated tether hook on each end. He attaches one hook to a loop on his wrist and the other tether hook is attached to the tool being used.

EVA tools on the Space Shuttle and the ISS can also be divided into two types, general-purpose tools and unique application tools. General-purpose tools, such as the EVA ratchet and the portable EVA power tool, are used for various repair tasks. Unique application tools are designed for a unique task or for a specific spacecraft, such as for repairing the Hubble Space Telescope (HST).

These EVA tools are used for repairing satellites and for assembling and maintaining the ISS. Most of these EVA tools are stowed in EVA tool boxes located outside in the Space Shuttle payload bay or on the ISS airlock. Examples of general purpose EVA tools on the Space Shuttle and the ISS are the EVA ratchet with a 3/8-inch square drive, 7/16-inch hexagonal socket extensions of various lengths, adjustable wrench, vise grips, compound cutters, needle nose pliers, and a hammer.

A very important EVA tool used on both the Space Shuttle and the ISS and to service satellites, like HST, is a battery- powered tool known as the Pistol Grip Tool. This EVA power tool is very similar to a portable electric drill and driver. The Pistol Grip tool is a self-contained, computer-controlled, battery-powered portable power tool. It is used with various socket extensions and torque multipliers for removing and torquing mechanical fasteners, such as bolts. Torque, speed, and the numbers of turns can be programmed into this power tool.

## **HST Repair**

Though there have been several satellite repair missions in the past, like the successful repair of the Solar Maximum Satellite during STS-41C in, April 1984, the most famous satellite repair mission has been the repair mission of the HST. From the beginning, the HST was designed for servicing and upgrades of its main components and instruments by EVA astronauts during scheduled repair missions. NASA performed the first servicing mission to repair the HST during STS-61 launched on December 2, 1993. Using a variety of EVA tools, astronauts replaced several instruments to correct the mirror aberration and electronics boxes known as orbital replacement units (ORUs). HST was completely repaired and returned to service after 5 space walks by the EVA astronauts.

During these servicing missions of the HST, astronauts have access to the same general purpose EVA tools carried regularly on the Space Shuttle. Some additional EVA tools used to repair the HST included various sizes of hexagonal and Allen heads socket extensions, electrical connector tools, torque multipliers, and the Pistol Grip Tool.